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# The Co-Evolution of Mars' Atmosphere and Massive South Polar $CO_2$ Deposit

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Mars 9

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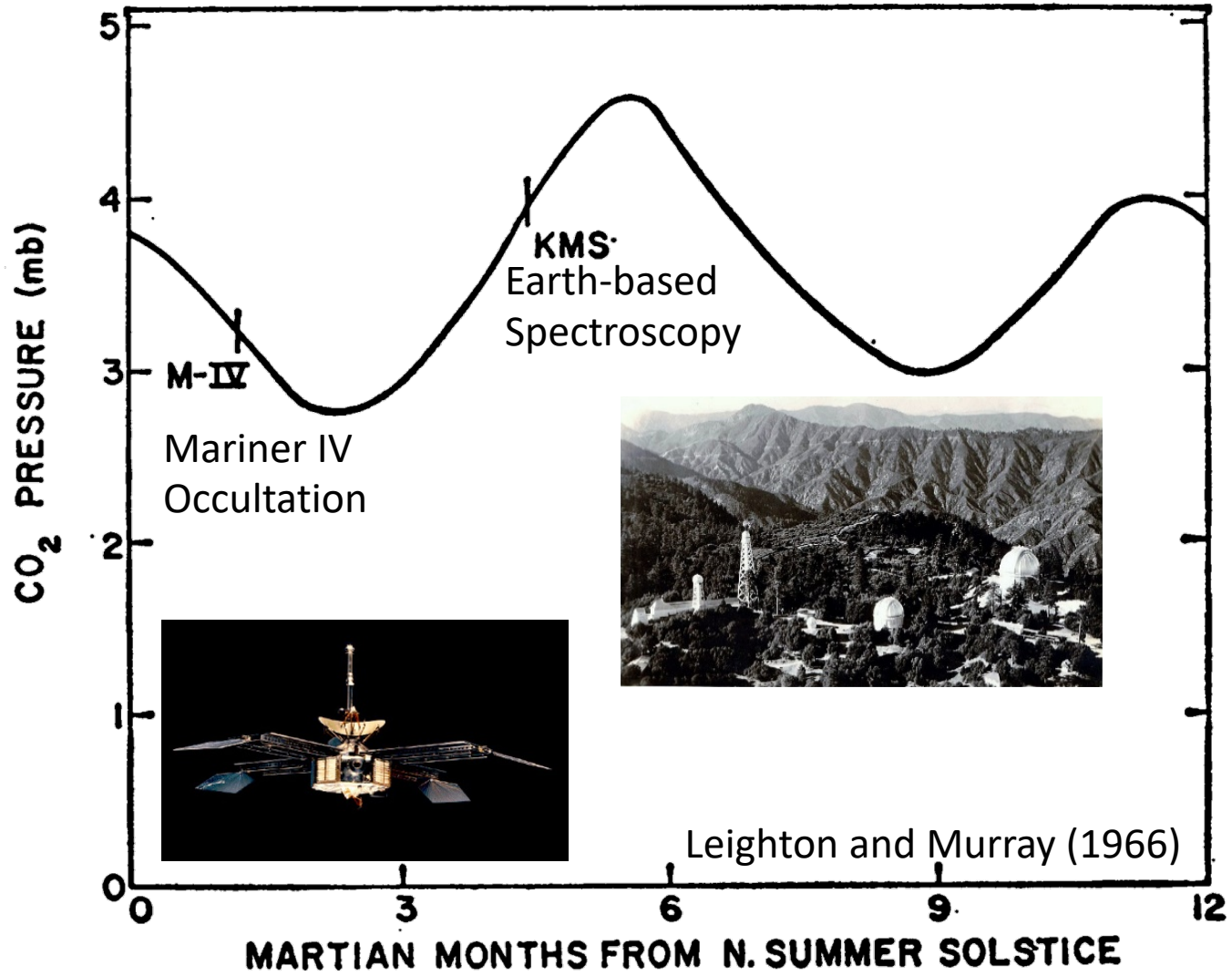
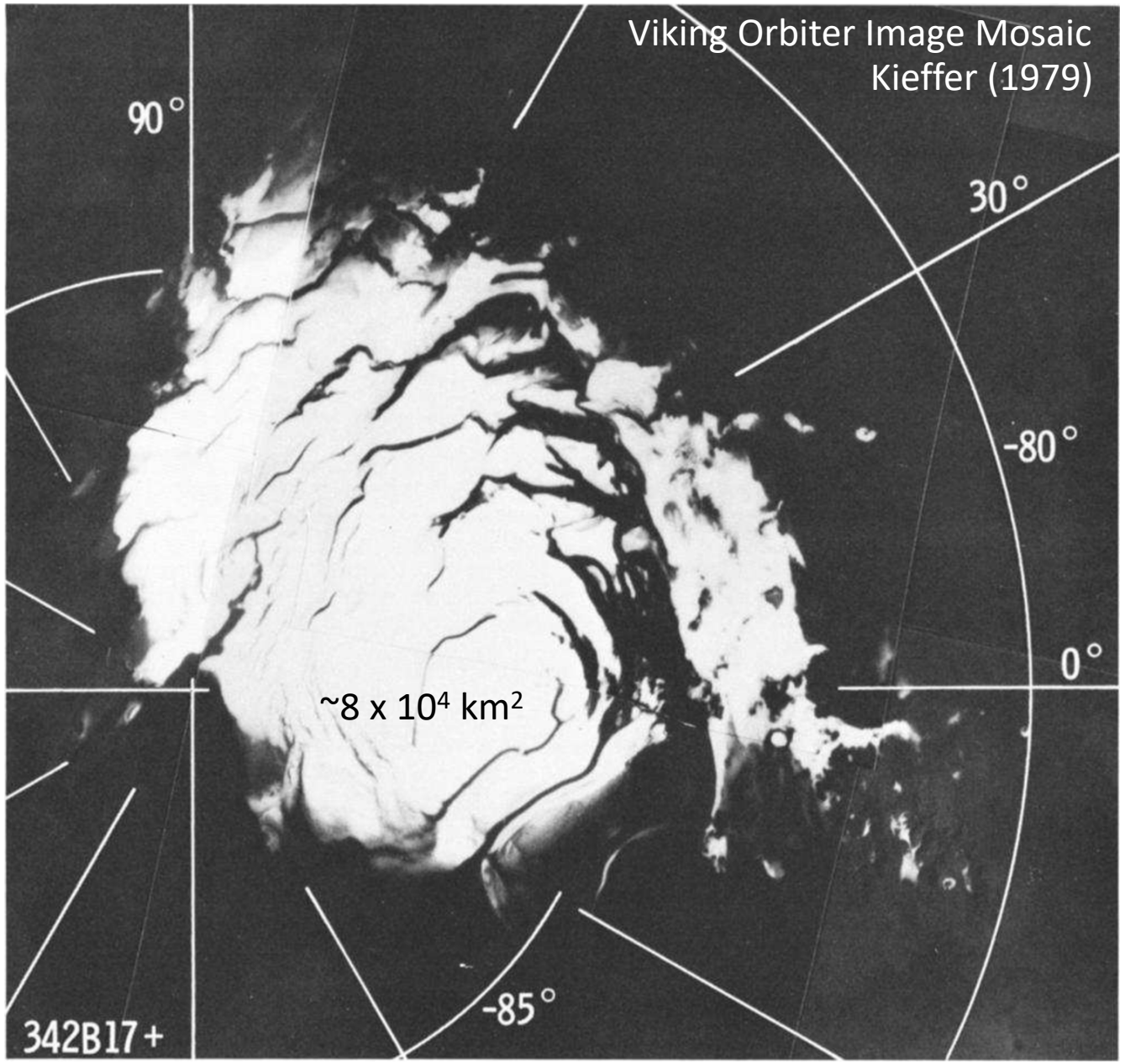
# At the Dawn of Mars Robotic Exploration



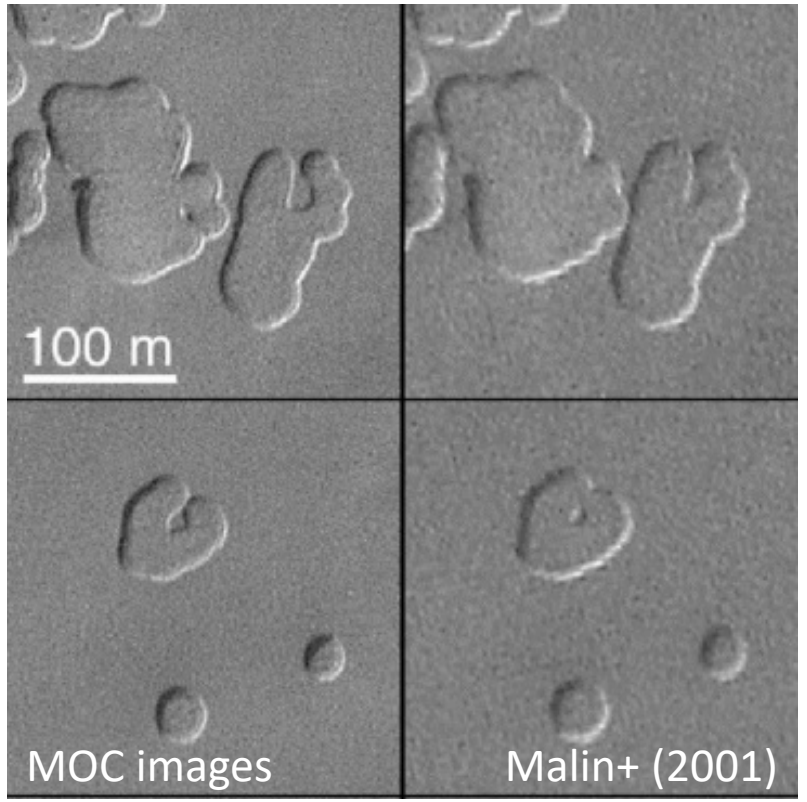



Prediction: Both polar caps are entirely $CO_2$ ice in equilibrium with Mars' $CO_2$ atmosphere.

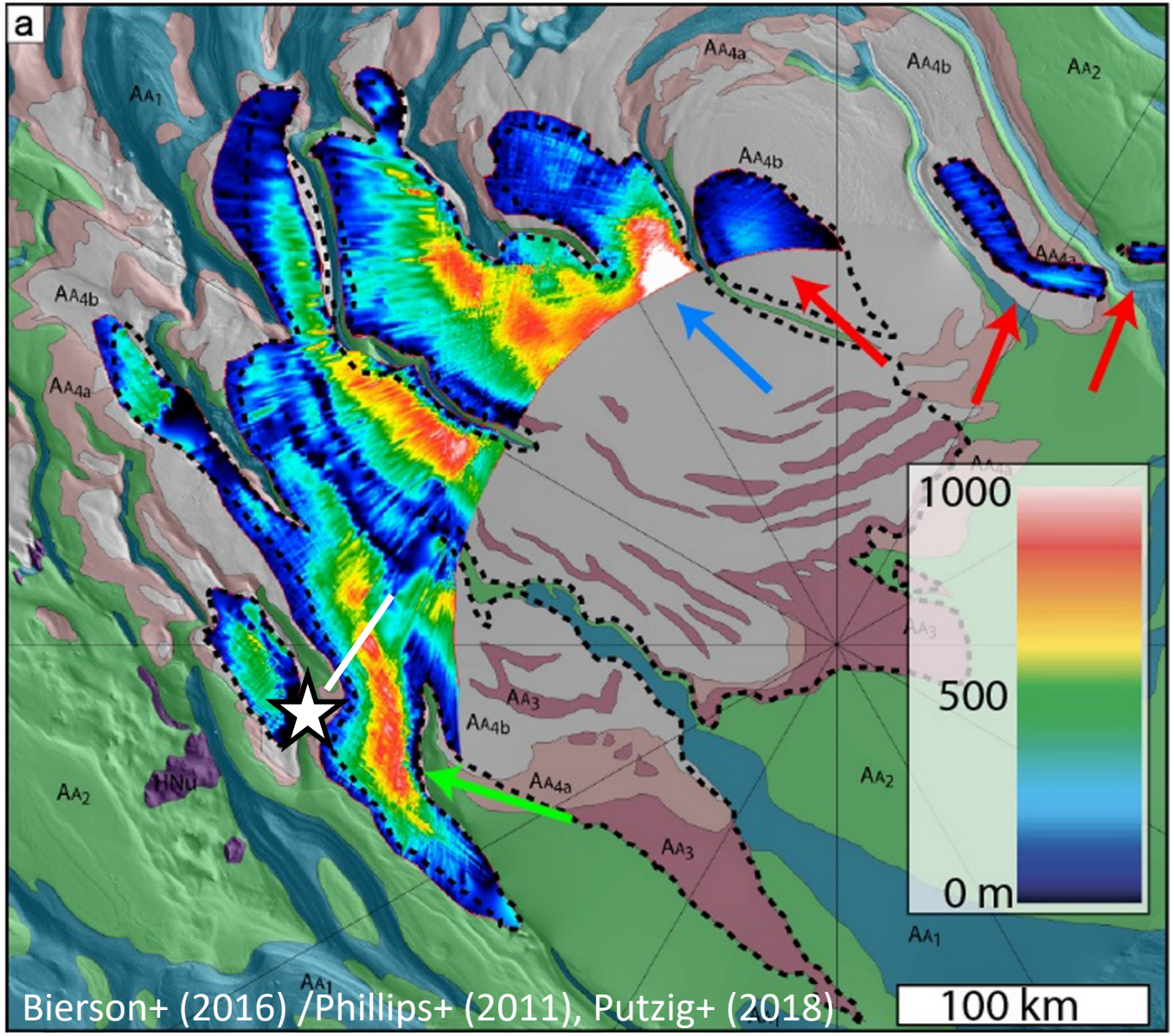
# What did we find? The RSPC overlying $H_2O$ ice.

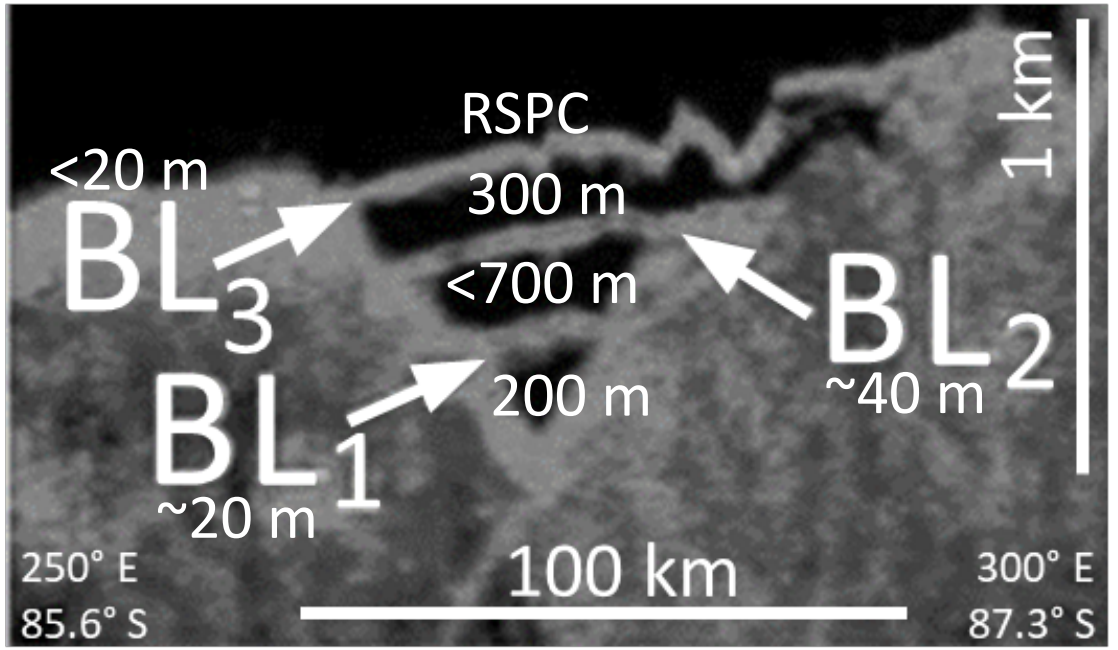



- "Residual South Polar Cap": Up to ~10 m thick surficial perennial $CO_2$ deposit
- ~1% the atm mass (Thomas+, 2016)
- Can't buffer atmosphere through obliquity variations



# Beneath the RSPC: A Massive $CO_2$ Ice Deposit




Previous models*:

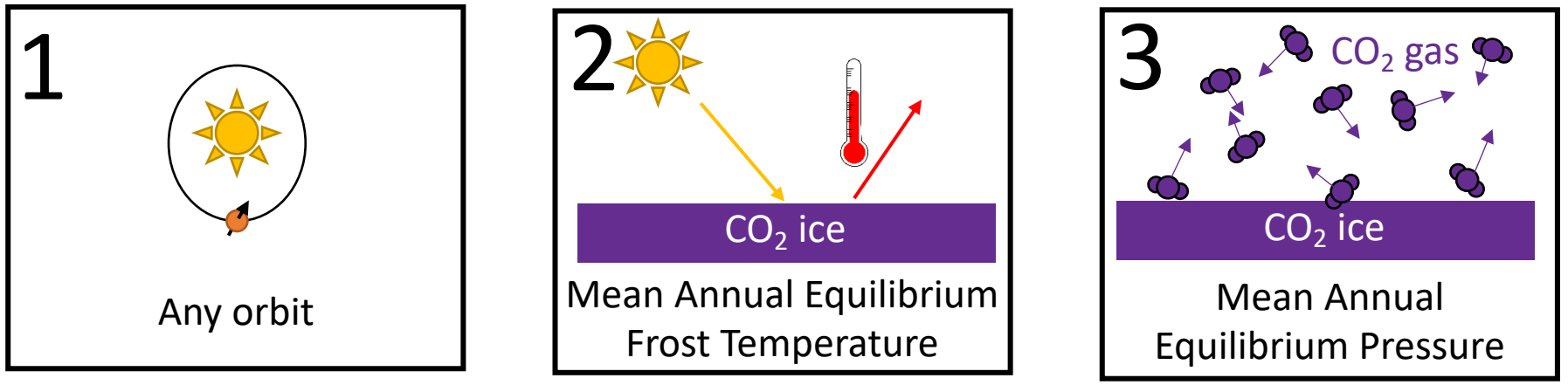
*Bierson+ (2016), Manning+ (2019)

- $CO_2$ deposit emplaced during periods of low obliquity
- BLs insulate and seal in the $CO_2$ at high obliquity

~mass atm, up to 1 km thick, up to 3 $H_2O$"Bounding Layers"

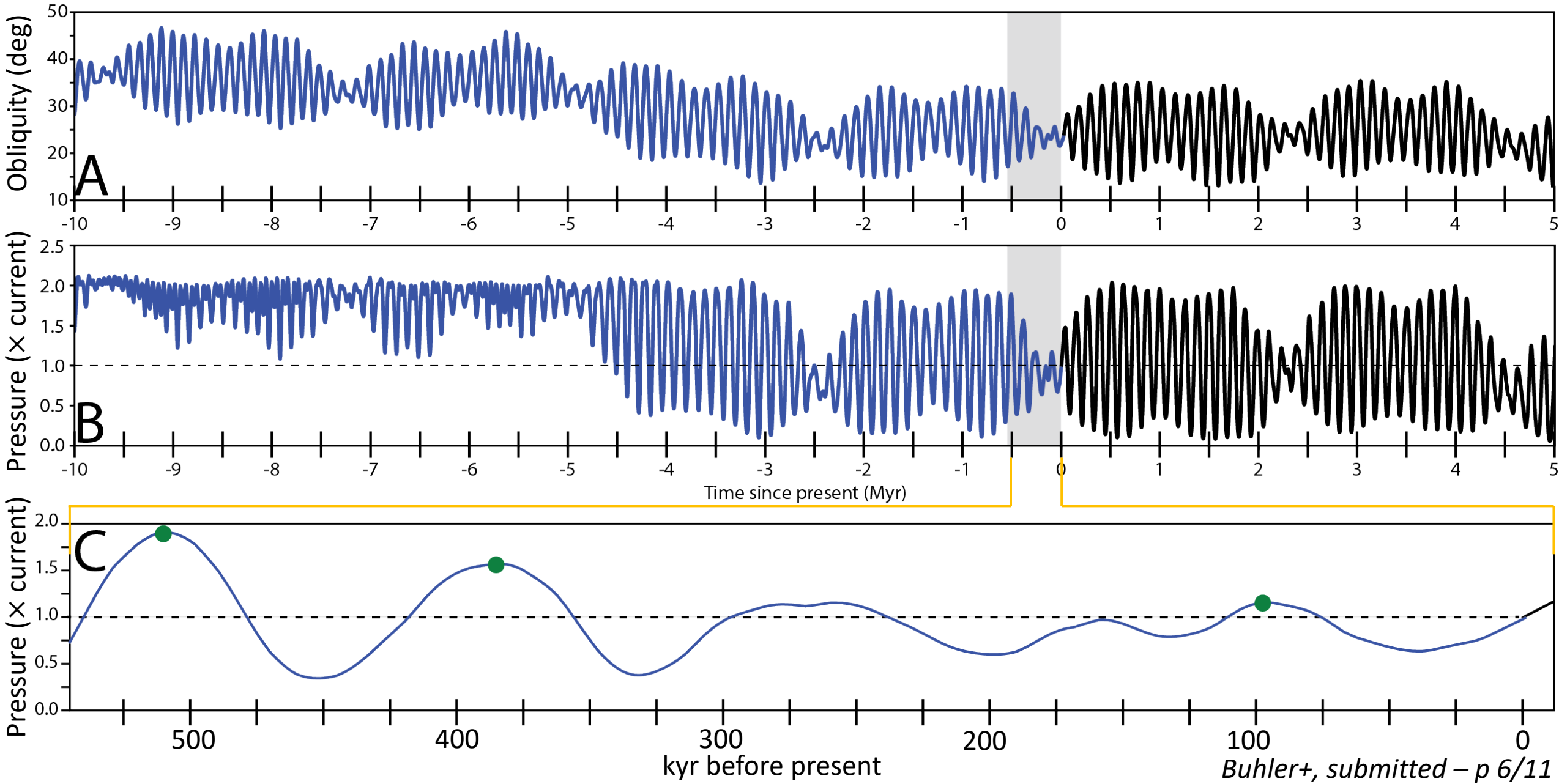
# Our Model Set-Up

## 1D Energy balance:



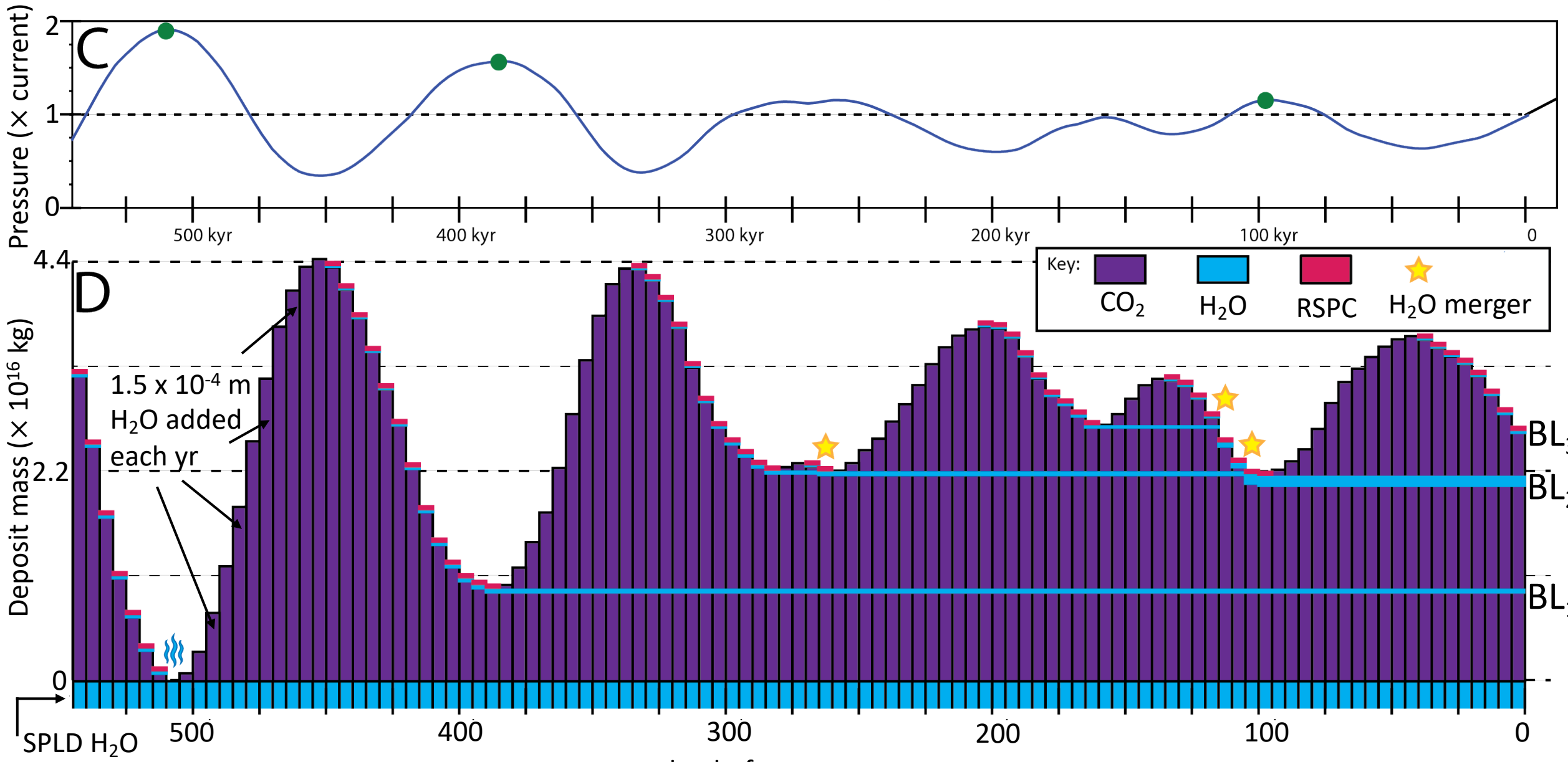

- Emissivity: 0.8, Albedo: $A_{CO_2} = 0.532 + 0.511 \times \cos(\theta_{solar})$
- $CO_2$ mass: atmosphere + deposit = $5.4 \times 10^{16}$ kg
- Account for elevation change from finite cap thickness, with MCID area = RSPC area ($8 \times 10^{10}$ $m^2$)
- Different set-up compared to previous models: Vapor contact between MCID and atmosphere at all times.

# Mars' Pressure History




*Buhler+, submitted – p 6/11*

# Deposit Stratigraphic History

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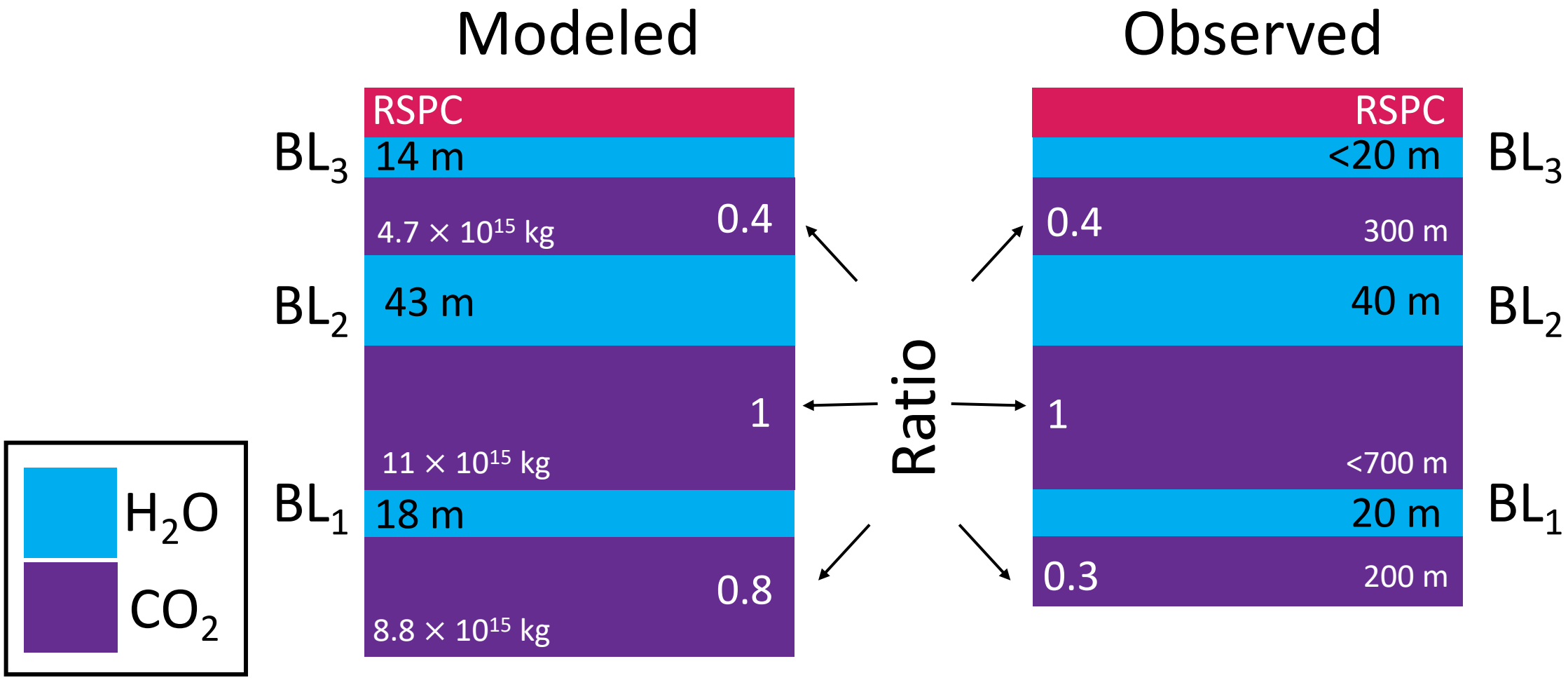
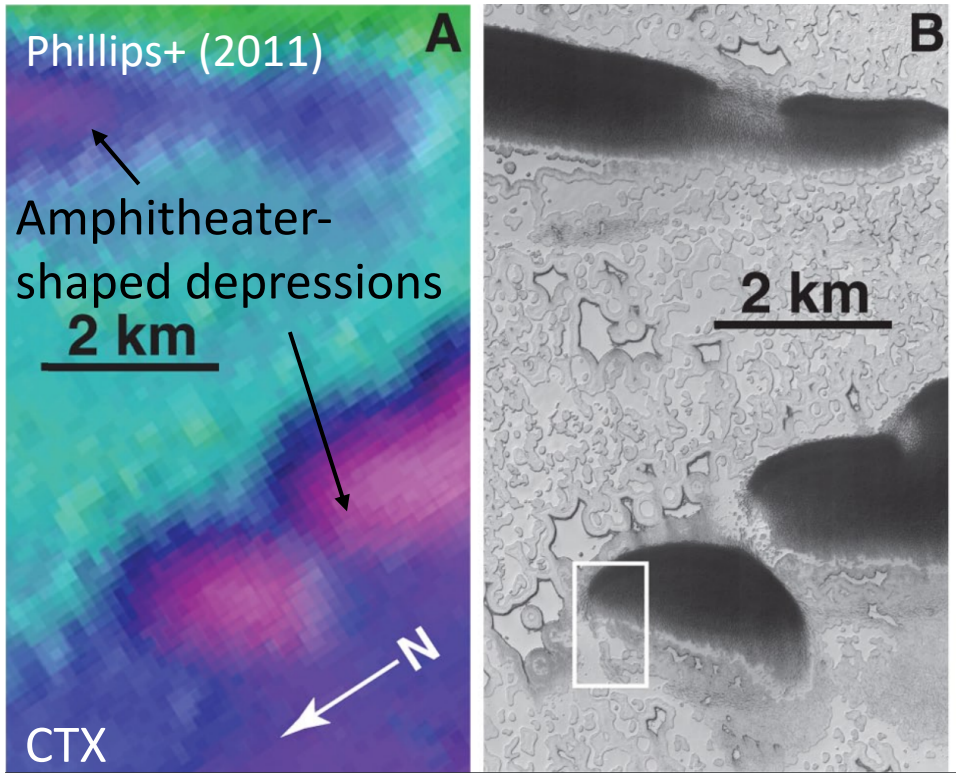
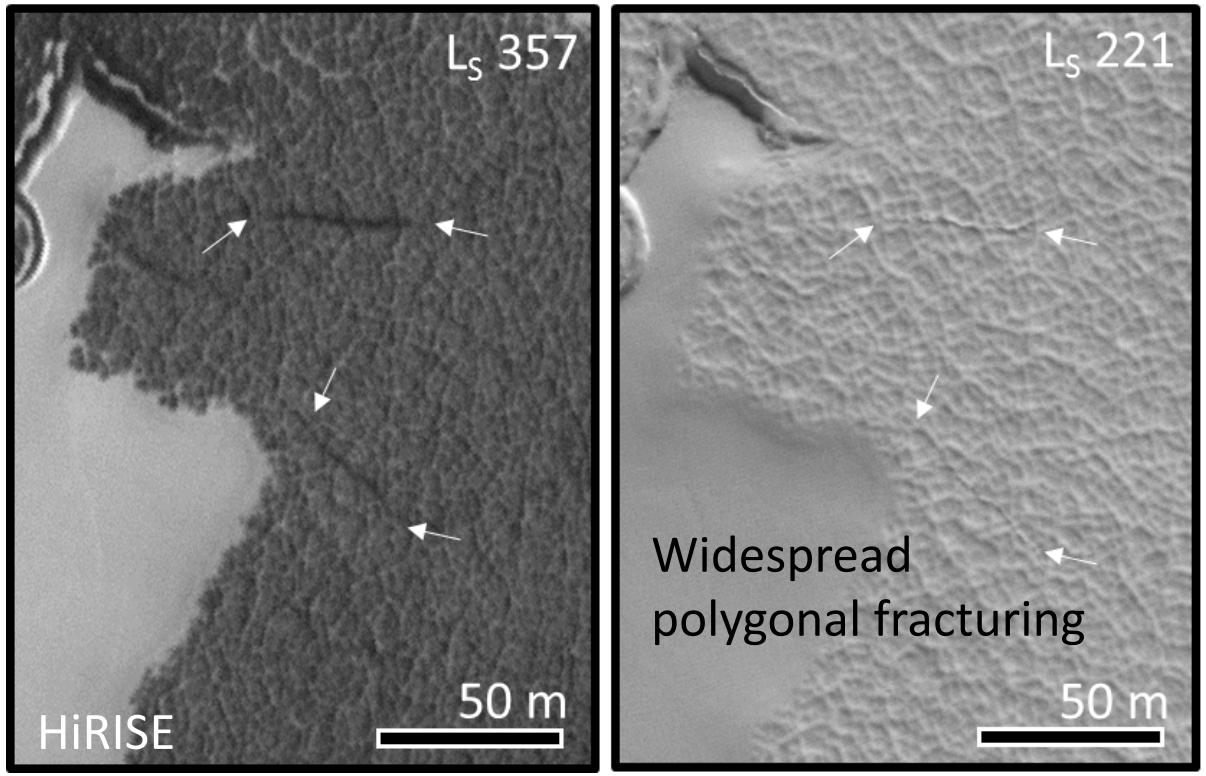
# Modeled & Observed Stratigraphy




**$CO_2$ layer mass** depends on **amplitude** of obliquity maxima,
**$H_2O$ BL thickness** depends on **time** between obliquity maxima

# Can $CO_2$ sublime beneath the $H_2O$ ice?

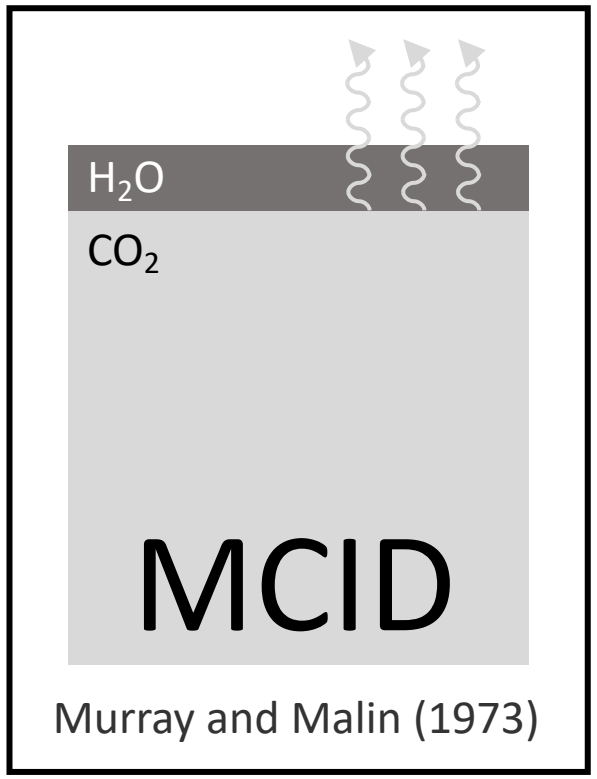



- Large dark areas appear by ~$L_S$ 300 (or earlier)
- Whether $CO_2$ beneath the $H_2O$ will sublime depends on vapor contact with the atmosphere; depressions and widespread polygonal fracturing consistent with contact
- Thermal diffusion model: 40 m thick $H_2O$, exposed at $L_S$ 300, k = 3.5 W $m^{-1}$ $K^{-1}$ -> thermal wave such that top of $CO_2$ beneath $H_2O$ sublimes for ~quarter of a Mars year

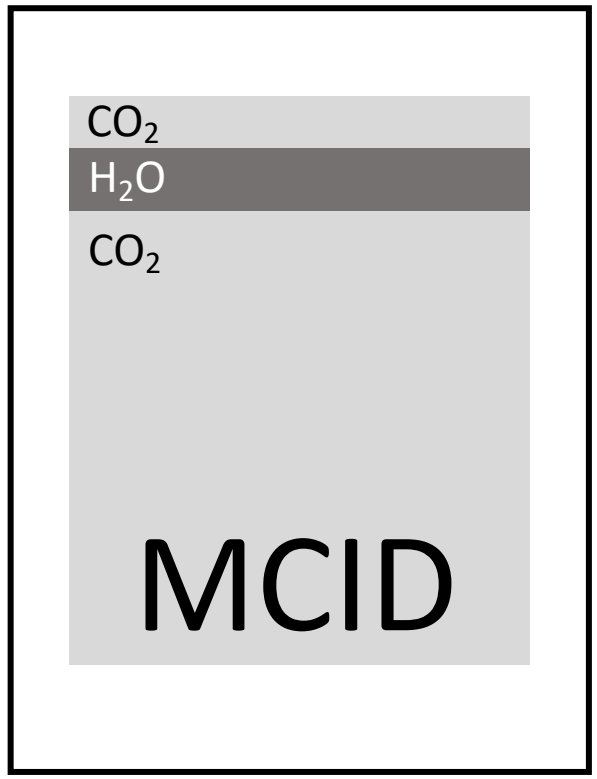
# Is the RSPC a “Fantastic Coincidence”?

Exposed “scum” ($H_2O$) dark, less volatile, destabilizes $CO_2$ beneath

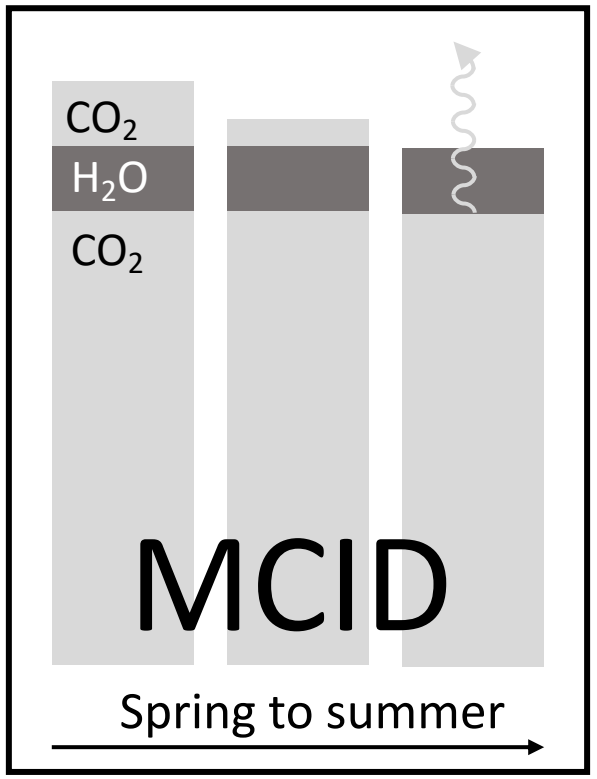



Murray and Malin (1973)

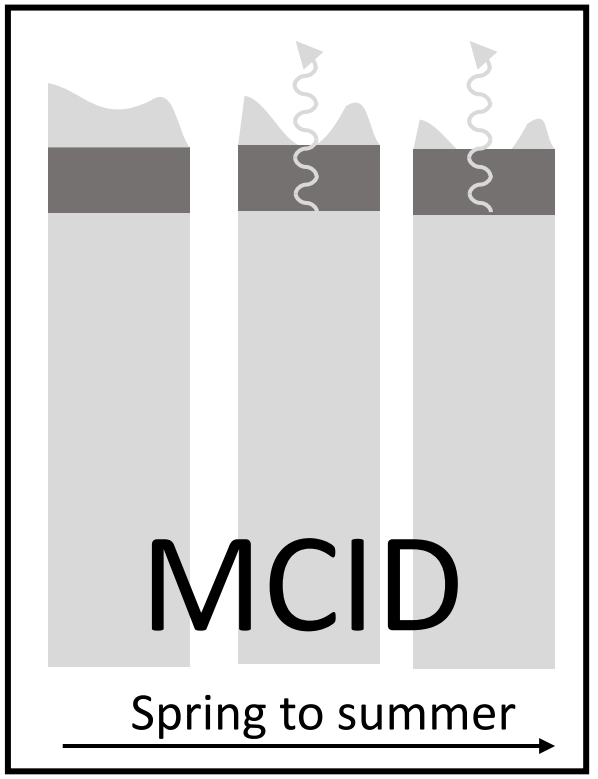
But then, pressure increases! Restabilizes $CO_2$




1D: duration of end-summer $H_2O$ exposure can adjust, controlling amount of $CO_2$ sublimation

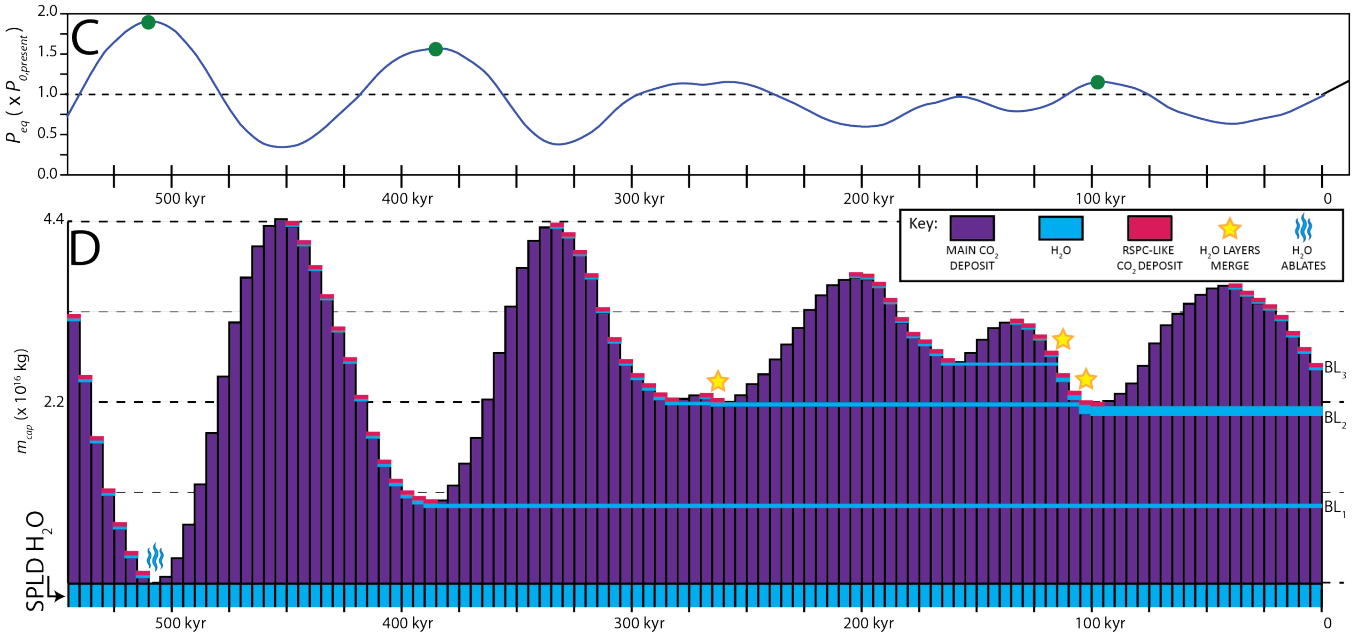



Pitting a complication, in 2D duration *and* area can adjust

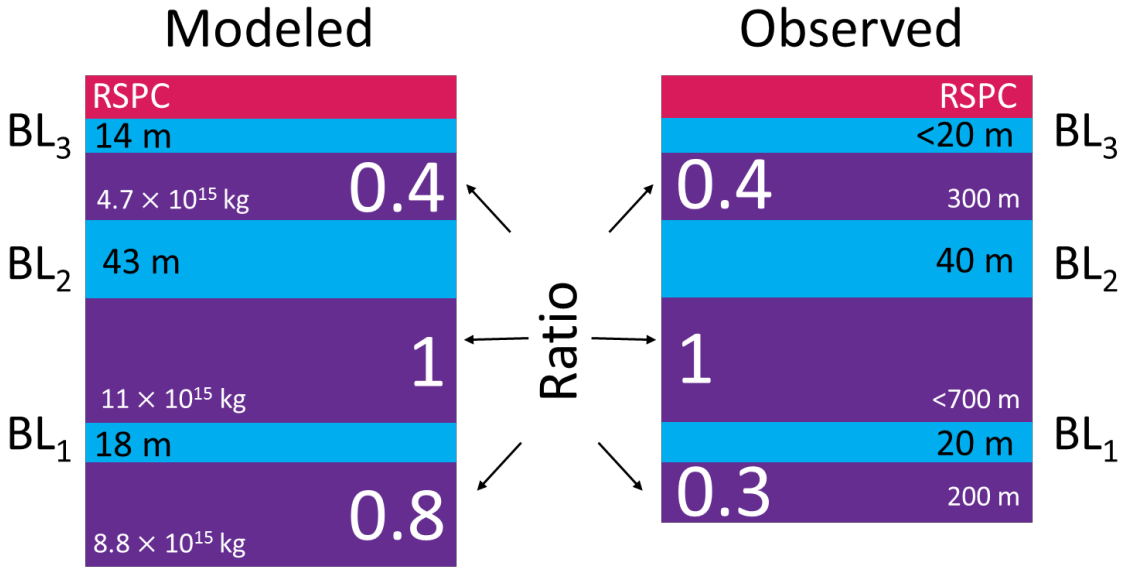



RSPC is expected if the $CO_2$ beneath the $H_2O$ can exchange mass with the atmosphere; i.e., MCID-atmosphere exchange.

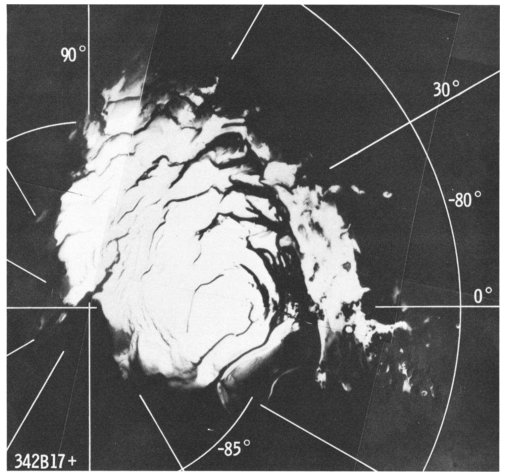
# Conclusions




We offer a model of the stratigraphic development of Mars' massive $CO_2$ ice deposit (MCID) through continuous vapor contact with the atmosphere that provides ages for the layers.




Model stratigraphy matches favorably with the observed stratigraphy.




Our model framework predicts the RSPC in equilibrium with the atmosphere.

*Buhler+, submitted – p 11/11*